DEEP SEA SOUNDINGS

AND

The Influence of Microscopical Algae on Deep Sea Life,

WITH A FEW REMARKS ON EVOLUTION.

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BY

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MEMBERS OF THE AMERICAN SOCIETY OF MICROSCOPISTS—I think we may very reasonably congratulate ourselves upon the results attained at the meeting of the National Microscopical Congress, at Indianapolis, two years ago, and the first meeting of the American Society of Microscopists, at Buffalo, last year. The published proceedings of these meetings show that many interesting, and some very valuable, papers have been read and discussed, some notice of which I might, in review, here present to you. Again, I might say something about the wonderful improvements, optical and mechanical, which have recently been made in what Sir Thomas Browne quaintly calls, "The intellectual tubes, which give thee a glance of things that visive organs reach not;" but a presentation of these, or similar topics, appears to me less desirable upon the present occasion, than a discussion of some special question with which your speaker may be supposed to be reasonably familiar. I take, then, for my theme, "Deep sea soundings, and the relation of microscopic algæ to deep sea animal life, with a few remarks upon evolution." If we are ever to be conducted by natural science to a solution of the question respecting immutability of species, it must be from a careful and reverent study of nature, conducted with that plain sense and honest purpose which is neither alarmed, on the one hand, lest the Creator be thrust out of his place, nor too proud, on the other, to acknowledge it, should there be found legitimate and substantial proofs of the existence of a Divine Being. I suppose that in some form or other, more or less modified,

evolution is, to-day, received by all who have thought much upon the subject, for "the acceptance of the principle of variation and natural selection does not involve a belief in hap-hazard and incessant change, but a continuing readjustment, which may, or may not, according to circumstances, involve considerable changes in a given time; in fact, such an adjustment to surroundings as will only, throughout all time, exhibit an harmonious adaptation to all circumstances;" nor can I, for my part, see that the holding of this belief is in any way incompatible with the possession of Christian graces, or the exercise of the sublimest faith. It is not, however, the discussion of this question itself which I have here in view, because, as I have said, in some form or other, almost every student of nature admits it, but rather the presentation of a few thoughts which, in some respects, bear upon it, and which have been suggested to me from the study of deep sea soundings, obtained during the late cruise of the United States Steamship, Tuscarora. Xenophon tells us that the "Ten thousand" shouted when they looked upon the sea. What wonder. Who can watch the swelling tides, as with unerring regularity they beat the never ending systole and diastole of nature; who can behold the everchanging lights that in the garish, babbling day, gleam in softened splendor over its surface, or in the darker night, from the pale moon, or a thousand stars, shimmer across its restless bosom, or which flash in long, lingering lines of phosphorescent glow, without having the deepest emotions of the heart stirred? If from the ten thousand, when the weary parasangs were ended, when they saw again the blue waters, and felt again the whistling breezes of the Euxine, a shout went up, and they looked upon the sea as upon the face of an old friend, far more from the naturalist, when he beholds from the iron coast, as from some Pisgah's top, the immensity of the world of ocean life, should go up a heart cry of satisfaction; for he has learned that no more under the vast extent is the waste of utter darkness once supposed; an abysmal cavern, where all life was crushed under the enormous pressure, and where exploration was surrounded with insuperable difficulties. He knows that far below the reach of stormy winds, undisturbed by the vast weight of the superincumbent waters, are wonderful and delicate forms of life; and that in the 140,000,000 of square miles added to the field of natural history research, he will realize a veritable land of promise. Homer speaks of the sea as unfruitful; and barren indeed it was to his blind eyes, and so to very modern times it has remained. With truer poetic instinct he calls it again, "abounding in great monsters." Wonderful things, marvels in the field of Biology. Wonders in the domain of Physical Geogra-

phy, where, as Sir Wyville Thompson says, "every other question had been investigated by scientific men with consummate patience and accuracy. Every gap in the noble little army of martyrs striving to extend the boundaries of knowledge in the wilds of Australia, or the Zambesi, or towards the north and south pole, had been struggled for by earnest volunteers, and still the great ocean, slumbering beneath the moon, covered a region apparently as inaccessible as the Mare Serenitatis."

Not many years ago, the English naturalist, Edward Forbes, concluded that the bathymetrical terminus of life was at a depth of 300 fathoms—his "zone of deep sea corals." Michael Sars first questioned this; and in 1860 Dr. Wallich proved that at depth of 2,000 fathoms, *i. e.*, 12,000 feet, or over two miles, not merely the lower forms of life, such as rhizopods and diatoms, existed, but also crustacea, bryozoa, and echinoderms; and when the submarine cable between Algiers and Sardinia was taken up for repairs, A. Milne Edwards reported numbers of living corals and molluscs which were found adhering to portions that had been sunk from 1093 to 1575 fathoms. The person, however, who undoubtedly gave the greatest stimulus to deep sea explorations, was the Norwegian naturalist, George Ossian Sars, whose investigations date back to 1867. He found, at great depths, not a poor and oppressed fauna, but, on the contrary, a richly developed and varied animal life. In 1867, the Superintendent of the United States Coast Survey organized an exploration of the Gulf Stream. The dredging was under the charge of Count L. F. de Pourtales, and it revealed the existence of a wonderfully rich fauna. The next year, Prof. C. Wyville Thompson, Dr. W. B. Carpenter, and Mr. J. Gwynne Jeffreys, stimulated by the discoveries of Sars and Pourtales, and furnished with the most approved apparatus, commenced a cruise of three years in her Majesty's vessels "Porcupine" and "Lightning," during which they made valuable additions to our knowledge of deep sea life, temperature, and currents, as detailed in Sir Wyville Thompson's most interesting book, "The Depths of the Sea." Subsequently, December, 1872, the celebrated cruise of the Challenger commenced, also under direction of Sir Wyville Thompson. Sailing over 69,000 miles of ocean, for a period of three and a half years, an immense collection was made in all the departments of natural history, which has been assigned to specialists for discussion and report; and for this purpose the government has appropriated some £4,000 per year, and which, when completed, will form the largest single contribution to science ever made. In 1873, the United States steamship, Tuscarora, under charge of Commander George E. Belknap, was detailed to

make a series of soundings in the North Pacific, with reference to a practical route for a submarine cable between the United States and Japan. A great number of soundings were made, and numerous valuable facts ascertained, in reference to temperature at extreme depths, currents, and contour of the ocean bottom. These soundings were placed in my hands for examination; but as yet no appropriation has been made to meet the necessary expense, and but a small portion have been thoroughly examined as to their organic contents. They have generally proved to be pretty rich in the remains of animal and vegetable growths, even from the depths of over three miles; and these remains, in many cases, were undoubtedly those of organisms which had lived at great depths. The labels accompanying the soundings record all the details that could be desired. Taking one as a specimen, we read:

> **Pacific Ocean, Lat. 43°, 47 N., Long. 150° 02 E.**
> **June 18, 1874. Hour, 4h, 50m, 17s., A. M.**
> **Cast No. 30. Depth, 4234 fathoms.**
> **Temp. surface 49° 3. Temp. 1100 fathoms. 33° 23.**
> **Temp. air, D. B. 50°, W. B. 50° 4.**
> **Barometer, 30.05. Thermom. attached.**
> **Apparatus used, Thompson's. Line, Piano wire, No. 22.**
> **Machine for bottom, Belknap cylinder, No. 1.**
> **Sinker 8″, shot, weight 74 lbs.**
> **Wind, S. by W., force, 4.**
> **Weather, c. g. Clouds, cir. strat., and cum.**
> **Sea, smooth. Time occupied in cast, 2h. 16m. 52s.**

This sounding, it will be noticed, was from a depth of almost 5 miles, 25,404 feet, and is one of the deepest reliable soundings ever made; and this depth corresponds very nearly to the height of the highest mountain on our globe, Mt. Eveerst, one of the Himalayas. The deepest sounding made during the cruise of the Challenger was between the Ladrone and Caroline Islands, 4575 faths. Lat. 11° 24 N. Long. 143° 16′ E. Deeper soundings than these have been reported, but we now know that, from the imperfection of the sounding apparatus, they have been greatly exaggerated. The particular sounding of the Tuscarora, to which I have just alluded, contained no sand, nor any calcareous tests, nor any signs of foraminifera; but there were abundant remains of vegetable life, chiefly diatoms; Coscinodisceæ, Biddulphiæ, Asterolampreæ. etc., with a few sponge spicules and fragments of polycystinæ, all microscopic organisms. From a general comparison of all the soundings hitherto made, Mr. Murray, the naturalist of the Challenger, states that the average depth of the ocean can not be less than about 15,000 or 16,000 feet, while the aver-

age height of the land above the sea level is only about 900 or 1,000 feet. It may not be uninteresting to consider now, for a moment, the manner in which these deep sea soundings and dredgings are made. The lines are let out from a block attached to what are called "accumulators;" there are three of these, and they are made by fastening bands of india rubber, about three feet in length, between discs of wood, and as these bands are capable of being drawn out to twice this length, they thus break any strain that may come on the sounding or dredging lines from the rolling or pitching of the ship, and which would otherwise break the line. The line used for the Tuscarora soundings was Piano wire, No. 22, armed at the bottom with a metal cylinder having a valve opening upwards, and weighted by a shot of 60 to 70 pounds. Above this was attached the thermometer, incased in a strong glass tube, thus taking off the pressure which otherwise would have crushed the instrument. The pressure, at a depth of four miles, amounts to 8,000 pounds on the square inch, and, despite all precautions, the thermometer is often crushed; besides the thermometer, there is attached also at any desired place, a water bottle for obtaining specimens of the water at varying depths. The construction of the water bottle, and the mode of using it, I show you here. The examination of sea water from great depths was one of the special objects of the Challenger naturalists; its specific gravity, its temperature; the per cent. of carbonic acid, oxygen, and the various salts in solution, all which have a bearing on the character and amount of deep sea life. Mr. Buchanan, the chemist of the expedition states that in bottom water the largest per cent. of oxygen is found in Antartic regions, and it is greatest over diatomaceous oozes, and the least over the red clays containing peroxide of manganese. It is a singular fact that the oxygen diminishes down to the depth of 300 fathoms, where it attains a minimum, after which the amount increases. One of the specimens of sea water obtained during the Tuscarora soundings, September 22, 1873, and which had been closely corked, showed, June 26, 1876, myriads of living diatoms, Amphoræ, and at the present date, August, 1880, it is full of bright green spores. It is, at present, loosely corked, and once or twice I have added distilled water to supply loss from evaporation. The tube, or bottom cylinder, projecting beyond the weight is, upon striking the bottom, driven by the weight, into the mud or soft clay, to a depth of almost two feet, or on harder bottom, say six to eight inches. The time required for the sounding is, of course, very much longer than that which would be required by a body falling freely to an equal depth, owing to the friction upon the line as it runs through the water, and it is to relieve

this friction that the steel wire is used. The first few feet are passed over in somewhat near the time that a body would fall freely under action of gravity at the surface of the earth; but a depth is finally reached where the acceleration is very small, and the motion of descent is nearly uniform. Thus the line runs out about 1 mile in 9 minutes; two miles in about 20 minutes; 3 miles in 35 minutes; 4 miles in 55 minutes.

This last distance would have been described in 26 seconds by a body falling freely.

Mr. Murray states, in an interesting lecture upon the cruise of the Challenger, from which I have taken the above statistics, that the deepest sounding of the Challenger, 4575 fathoms, was run in 75 minutes. Of course an equal amount of time is required to wind in the line, some two and one-half hours in this case. Upon striking the bottom, the weight becomes detached, and therefore, all over the bed of the ocean, wherever these soundings of the Tuscarora and Challenger were made, are masses of iron, so that. small as are the quantities of material obtained, you will see that they are really very costly, and therefore should be very carefully examined. The mineral character of the soundings, and the depth, and temperatures, as obtained in the cruise of the Tuscarora, are now being studied along with those of the Challenger, and for this purpose I have sent them, by permission of the Smithsonian Institution, to the Challenger office, Edinburgh, upon request of Sir Wyville Thompson, but the organic contents, which are mainly microscopical plants and animals, will require a very long and patient study, but one which will well repay, judging from the yield of those that I have already examined. The detaching of the weight, so that only the friction of the line, and the weight of the cylinder is to be overcome when raised, was the invention of passed Midshipman, afterwards, Lieutenant Brooke, of the U. S. Navy, and the use of the steel wire was suggested by Sir W. Thompson, though it was not employed, I believe, in the Challenger expedition.

When the dredge and trawl could be used, as they often were on the Challenger at the depth of over three miles, all the marine invertebrate types, as well as fishes were found, and also hydrozoa, polyzoa and corals. Brachiopids and annelids occur at all depths, and sea spiders, sometimes two feet across. The specimens brought up in the cylinders attached to the sounding lines are mostly microscopical, and it is these which mainly interest us here present, and the study of these suggests some novel ideas in regard to the manner in which deep sea life is sustained. These microscopical organisms are chiefly foraminifera, and radiolaria, belonging to the Animal Kingdom;

and the diatomaceæ, now universally recognized as minute algae. It is only necessary to describe them briefly, as they are well known to most here present. The foraminifera belong to the lowest order of animal life, the so-called protozoans. They have no special organs for assimilation or digestion. They secrete beautifully formed, and generally calcareous shells, or tests, often punctured with minute holes, and hence the name foraminifera; through these holes, or at a larger opening where the test is porcellaneous, or arenaceous, the sarcode (or soft fleshy substance) is exuded, branching in long root-like filaments (pseudopodia) never twice alike, and from their appearance in this condition, they are called rhizopods; some are so minute that millions may exist in a cubic inch, and often a sounding will consist mainly of these. Most of them, perhaps the majority, are surface organisms, and after death the calcarous tests fall to the bottom and form great beds somewhat similar to the deposits that in former ages gave rise to what are now the chalk cliffs of the Cretaceous formation; but on the other hand, as has been well established by my friend, Mr. Henry R. Brady, F. R. S., in his "Notes on some of the Reticularian Rhizopoda of the Challenger Expedition, Mic. Jour., Vol. XIX, 1879, we have positive evidence that foraminifera do live at the bottom of the deep sea, especially those with composite or arenaceous tests; I had already myself arrived at the same conclusion, from the study of the Tuscarora soundings, as published in the Annual Record of Science and Industry, 1875, pp. 149, et seq. The radiolaria are very minute animals, which secrete silica to form their solid portion or skeletons, sometimes external, and sometimes internal. This group requires yet a prolonged and patient study, and is, at the present time, undergoing a revision by Prof. Haeckel. I found these in the Tuscarora soundings always more abundant in the so-called red clay, and the naturalists of the Challenger are acustomed to speak of these soundings, according to the prevalence of one or the other of these microscopical organisms, as "globigerina (*i. e.* foraminiferal) ooze," or "radiolarian ooze."

Nothing can be conceived of more beautiful than the silicious skeletons of radiolaria, and no doubt many here present are familiar with them, under the name of "Polycystinæ from Barbadoes." The soundings of the Challenger and those of the Tuscarora, reveal in this group many new, and some very wonderful forms. The diatoms, which are also found so abundant in certain places as to constitute "diatom ooze," are everywhere present in the ocean; they have been supposed to be mainly surface organisms, but I am quite certain, from the study of the Tuscarora soundings, that these, as well as the foraminifera and radiolaria, do live at great depths. For example, the very deep sound-

ing to which I have already alluded, and which was taken south of Yeterop, one of the Kurile islands, consisted almost wholy of diatoms, not the pale and empty frustules of a semi-fossil deposit, at a depth of some five miles; but containing the well marked endochrome. An examination of some similar sounding freshly brought up, would settle this question, but among the many new and larger forms that demanded the attention of the naturalists of the Challenger, the question as to whether these minute organisms were at the time, living at great depths, was, so far as I am aware, undetermined, and no microscopical observations, so far as I am informed, were made on board the Tuscarora. I can see no reason why these organisms, so simply constituted, may not exist at the bottom of the ocean, equally well with the foraminifera and the radiolaria. It is not necessary for me to tell you what diatoms are. Every microscopist is familiar with their frustules, as test objects or things of beauty. It will suffice, for the information of those who may not know them, to say that they belong to the lowest order of algæ, and secrete an external shell or box consisting of two sculptured valves, with a more or less pronounced and generally smooth connecting zone, and containing a peculiar colored endochrome. The true reproduction is by conjugation, but they increase continually by a process of gemmation or self-division, and hence the name, diatom. The silicious valves are often marked in the most exquisite manner, and serve, as you well know, for test objects.

And now, before discussing the question how this deep sea life is maintained, let me say a few words upon the temperature of the ocean and the nature of the bottom. The general belief that at a certain depth the temperature was permanent at 4° C. or 39° Fahr., the temperature of fresh water at its greatest density, was generally rceived up to the time of the cruise of the "Lightning;" instead of this, the average temperature of the bottom of the deep sea, all over the globe, in temperate and tropical regions, is very near the freezing point of fresh water, in a few instances below this. Mr. Murray says, in the lecture to which I have alluded, that the mud brought up in a dredge, quite under the equator, was so cold that the hand could not be held in it for any time with comfort; and he remarks that bottles of beer and champagne were placed in this mud for a time with advantage. The sea water, as it becomes colder, steadily contracts to the freezing point, but never reaches this, *i. e.*, as low as —3.5° C., 25.7° Fahr.; but it frequently reaches 31° degrees Fahr. *i. e.* below the freezing point of fresh water; and yet this cold, as Sir Wyville Thompson says, is not inconsistent with abundant and vigorous animal life. It is now conceded that whatever may be the cause, and

there are various hypotheses to account for it which I can not here discuss, there is actually a general surface movement, or indraught, as Sir W. Thompson calls it, from the poles, chiefly the Antartic, towards and beyond the equator. That there is this renewed supply is indicated by the fact that the bottom temperatures are far below the normal temperature of the earth's crust, which is not far from 50° Fahr.

In these cold waters the animal types remind one of those found in the Secondary and Tertiary geological periods, and it would seem as though the general conditions of existence at these great depths had continued almost unchanged since the Cretaceous period. The great bed of the ocean at depths of, say 2500 fathoms and more, consists almost invariably of a tough, reddish clay. It is a silicate of the red oxide of iron and alumina, often containing nodules of peroxide of manganese, and it is supposed to be of volcanic origin; it contains, also, spherules of iron and nickel, "cosmic dust," supposed to have fallen from interstellar space. This tough clay is almost entirely free from foraminifera, but it is often well supplied with the silicious framework of the most delicate radiolaria and minute sponges. The absence of calcareous organisms is explained by Prof. W. Thompson, adopting the view already expressed by Williamson, and Prof. Bailey, by the excess of carbonic acid in the water at these extreme depths. Another class of soundings, say from 1500 to 2000 fathoms, consists of what is called globigerina ooze, containing not only this particular genus, but numerous other foraminifera. It appears almost chalky white when dried, and immense areas of the ocean bed are covered by this deposit, so that Prof. Thompson has stated that a portion of the Atlantic basin, and we might add the Pacific, has been occupied by a deep sea since the Cretaceous period, what he calls the "continuity of the chalk." It is not to be understood, however, that we are from this yet living in the Cretaceous period, any more than, as Prof. Verrill says, we are in the Glacial period, because glaciers still exist, and have persisted since the Glacial epoch. The great ocean basins appear to be of vast antiquity, and the relations of the abysal fauna of the Atlantic and Pacific to the Cretaceous, and somewhat later Tertiary, seems to be pretty certain; but these relations are only generic, and, except among the lowest order of animal and vegetable life, the foraminifera and diatomaceæ do not extend to species. The deposits that range in depth from 300 to 1000 fathoms, have the character, very often of what is called "green sand," containing, along with much organic matter, fine sand, and broken, colored crystals of quartz, feldspar, tourmaline, and minerals of a more or less glauconite character; numerous casts of the foraminifera, and their calcareous tests,

often with a rotten look, and mixed with sponge spicules, fragments of echinoderms, iron sand, fragments of iron ore, and sulphides of iron, readily attracted by the magnet after roasting. One can, therefore, after a little experience, give a pretty fair estimate, from its general appearance, of the depth from which any sounding was brought, and the general character of the diatoms I have found to be so pronounced, that I think I could tell, pretty certainly, from what quarter ter of the globe any particular sounding containing them was obtained.

Let us look, now, at the conditions under which life exists upon the ocean floor; and first, the enormous pressure at these great depths would seem to put any idea of such life out of the question. It has been computed that, at a depth of 2000 fathoms, a man would bear a weight equal to that of "twenty locomotives, each with a long goods train loaded with iron." Again, it is almost inconceivable that light can penetrate to these great depths. Not long ago Wilkes placed the limit to which light could penetrate as 82 fathoms. We have been accustomed to associate brilliant colors with the presence of abundant light, and also the possession of eyes. Torrel found in the Spitzbergen Sea, at a depth of 1,430 fathoms, brilliant crustacea; and Sir W. Thompson mentions that *Munida*, from a depth of 700 fathoms, had eyes unusually developed, and of great delicacy. What, then, are the conditions of life under such abnormal circumstances? For we do know that alike under the more quite waters of the Pacific, or those of the turbulent and treacherous Atlantic, there is a vigorous growth of animal and vegetable life, flourishing under conditions that we cannot well realize; and though, of the millions of square miles thus occupied, but here and there a point has been tried, the results have been wonderful beyond all expectation. What is this life existing under circumstances so different from the normal condition of the surface? What strange phenonomena are exhibited at these vast depths? Whence comes the food? Whence the oxygen necessary for the existence of extensive animal life? These are questions which have not yet received a satisfactory answer. Is it possible, as has been suggested by the Challenger naturalists, that there is enough of organic matter continually falling in the ocean to sustain life? And can it fall through four or five miles sufficiently unchanged in the shells of pelagian molluscs, foraminifera, and diatoms, that swarm, no doubt, in the surface waters? Mr. Murray, for whose opinion I have the highest respect, speaks of the deep sea animals as feeding on the bottom mud, of course he means mud charged with organic matter; but these animals have always existed there, and the organic matter would have been exhausted many years ago, unless we suppose the

surface supply continuous, and fully equal to the demand. If so, why over the red mud, which should receive this deposit, is a poorer fauna found, and does not the rich fauna near, or under the diatom ooze, point to this as one of the great sources, supplying not simply the necessary vegetable food, but there in the ocean depths, serving the same great purpose that is performed by plants at the surface, the supply of free oxygen? The carbonic acid expired by animals living all over the ocean floor is, no doubt, more obstinately retained in solution under the enormous pressure, and though its removal is partly effected by the sulphates, the needful supply of oxygen requires something more than these; and in attempting to show how this is effected, why should we set aside the relations known to exist in other parts of nature? The one grand conviction of the permanence and uniformity in the order of natural things is the sure guiding principle, and we must reason from the known to the unknown under the leading of rationally adopted analogies. The more extensive is one's acquaintance with nature, the more fully is one impressed with this principle, and it is applicable in all cases. I do not doubt, then, that on the ocean bed, as at the surface, animal life depends upon the previous existence of vegetable life, and that not far removed. It is quite true that the great fact which stares us in the face at first sight is the necessity of light for the vigorous growth of plants. Deprived of light, they are deprived of food, and starve. This action of light is the deoxidising of carbonic acid, whereby the plants become green, appropriating the carbon and liberating the oxygen. This was Priestly's splendid discovery. Now, Draper has shown in his "Chemistry of Plants" that the rays which are the most effective in causing the decomposition of carbonic acid are the yellow; and these are the rays that penetrate the ocean waters most readily; and some facts that I have noticed with regard to the diatomaceæ, show that they flourish with a very small amount of light. Even if it is difficult to understand how, in the dark caverns of mid-ocean, life such as we know does exist there can be sustained, a like difficulty meets us at the surface. Some of the Actinæ flaunt in the sunlight, others court the darkest shade. Some Molluscs bask in the noon-day sun on the surface of the rock, others bore their way into darkness in the heart of the rock. Thus, paradoxes and surprises meet us at every hand. From some experiments that I have made with the living diatoms, I have reason to believe that they act much more energetically in effecting the decomposition of the carbon dioxide than the ordinary plants. In the latter, by this process, the green chlorophyl is elaborated; in the diatom the endochrome is a rich, orange yellow

with shades of brown, and their growth is wonderfully rapid. I can see no reason why in the ocean depths, where the carbonic acid is very abundant, there should not be an immense and vigorous growth of the microscopic algæ, chiefly the diatoms. In fact, one of the most abundant of the diatom oozes, obtained during the Challenger soundings, was of great extent, and from a depth of 1950 fathoms, and nearly all of one species. Mr. Murray does not say whether they were living, but from the color, which was that of a mass of living diatoms, I have no doubt they were. And I think that we must admit that the sunbeams, at least such rays as are most efficient for the purpose of deoxidising carbonic acid, do penetrate to the ocean floor. It is impossible for us, at present, to judge of the character or amount of the light at these great depths. The photographic rays, the blue and violet, are soon arrested, and no tests based upon the action of the light upon sensitive tablets can decide with regard to the yellow and green rays. Besides, after the light has been sifted as it were, by the first few fathoms of surface water, the rays which have penetrated thus far may now, perhaps, pass on, with comparatively little absorption, in the clear, still waters below. The facts in our possession are too few, as yet, for us to reason much upon the subject. We only know that here at the surface, by some mysterious force—we call it life—the lowest orders of the vegetable world are unceasingly elaborating what we call organic structure, out of inorganic; and once thus elaborated, higher classes of organisms appear and are nourished on this, and somewhere, no one can tell where, it is no more a vegetable, but an animal which meets our astonished gaze. We find, then, at the surface, and at moderate depths, that there is one unbroken chain, connecting the meanest lichen whose rootlets break up the granite rocks, with the highest expression of animal life in man. Shall we look for other explanation in the abysmal caverns of ocean? Is not life everywhere the same, and does not animal life everywhere presuppose vicinal vegetable life? The sounding comes up a mass of microscopical algae; is it because, during the ages, their imperishable silicious husks have been dropping, though carried first for thousands of miles by ocean currents, through the depth of four or five miles, until now the ocean floor is strewed with them? And if so, then these forms should be, not those found at the surface above, but those which have flourished in the warmer waters many thousand miles away. For my own part, I see no evidences of this; and so far as I am aware, no fresh water forms, (which should, where great rivers like the Amazon, for instance, pour huge volumes of water into the ocean, be carried on and deposited

with the surface or pelagic forms) are ever found. The living diatoms are all more or less firmly anchored—some on strong stalks, some encased in tubes, some in tough slime or jelly, and some are parasitic, and when they die they are never carried far from their native homes. To me it is much more reasonable to suppose that in the deep sea, they can, and do, live, equally with higher animal organisms, and in some way, little understood at present, under the stimulus of light which may be near darkness to us, serve the same purpose as the rich vegetable growths in the surface waters. That the water is aerated by the winds and storms at the surface, and that the descending currents go down more richly charged with oxygen, and that a certain amount of organic matter, appropriated by deep sea animals, is constantly dropping from the surface, no one doubts; but it does seem that such supplies must be too scanty to sustain the life which we now know exists there, but of whose extent we have very little comprehension—somewhat such knowledge as would have been obtained by one absolutely ignorant of the vegetable and animal life on the surface of our globe, by dropping out a sounding line or dredge, here and there, from a balloon, when sailing in the atmosphere above.

One cannot study these little organisms, and observe the manifold effects of life displayed in the minutest specks discernible by the microscope, without asking what is this life? When and where and how did it begin? Is it something inherent in matter, or is it something supervened somewhere in time upon a collection of atoms? The latter has been the generally received opinion. That there really is what Huxley has termed a "Physical Basis of Life" *i. e.* some kind of matter, "protoplasm," (for "Bathybius" has been consigned to the vast deep, never to rise again) appears, as he says, "when first apprehended to be a doctrine shocking to common sense." But there are many thoughtful, reverent men, and their number is increasing every day, who not only believe this, but even think they can comprehend the existence of life in the fire mist of the condensing nebulae. It is neither an irreverent, unscientific, or unthinkable idea. It is just here (although he may hold, with Paul, that "the eternal power and Godhead" may be clearly seen from the things that are), that in dealing with phenomena, and assuming the perfect uniformity of natural law, the scientist is too often accused of irreverence, because he does not at every step introduce an appeal to Divine power. In truth he begins with this as a postulate. No thoroughly scientific man would dream of denying it; without this, hypotheses have no value. When Laplace made that notable answer to Napoleon—who had said, "they tell me you have written a large book on the system of the universe,

and never even mentioned its creator"—"Je n'avais pas besoin de cette hypothese-la," he simply said what was true; he reasoned logically from his premises, there was no call for Divine interference; the denial of a leading power did not enter his mind—its existence he had not a thought of questioning. None but shallow, noisy pretenders make such denial; and even then, however it may do for them subjectively, objectively it will not answer. "I deny your existence," said a philosopher of the appropriative school, to the one who had appropriated him. "Come along, all the same," said the unpsychological policeman. If we ask the question, can the mere coming together of carbon, hydrogen, oxygen and nitrogen, as such, and possessing individually only properties which we have hitherto recognized as chemical and physical, can the coming together of these (elements of protoplasm, so far as we know,) develop life? Mr. Huxley (and also Prof. Tyndall) if I understand him, answers yes; and Mr. Huxley, in his Lay Sermons, institutes a parallel between the new properties assumed, when oxygen and hydrogen unite to form water, and those manifested when the protoplasmic elements combine to form that substance, being in each case properties entirely different from those possessed by the components. Now, so far as the compound analyzed by the chemist is concerned, *i. e.*, for dead protoplasm, the parallel is just; but for living protoplasm we must evoke something more—something which mere chemical affinity, so called, will not produce; in some way the manifestation of a force utterly different to anything before recognized as either physical or chemical. Between the properties of the new compound, water, and its components, and those of dead protoplasm and living protoplasm, there is a vast difference. Water has no power of compelling further union of hydrogen and oxygen to form more water, nor can dead protoplasm form more protoplasm; but the living protoplasm has this power. It seizes with an iron grasp the atoms of oxygen and carbon, of hydrogen and nitrogen, compelling them to quit their former associations, and now, not only to become a part of its own self, but to manifest the power in turn, of compelling in like manner other atoms. I am therefore disposed to consider that each elemental substance posesses in itself an evokable property under proper surroundings, manifest in what we call organic, but masked in inorganic structures; and that it is by virtue of this evoked property (polarity) that determinate molecular arrangment is assumed and living structures constituted; in fine, that life belongs to the atom itself, as a force masked in all those combinations which we term inorganic, somewhat as the magnetic forces are masked in the soft iron molecule. With all physical life

goes duality; we cannot separate it, *i. e.*, we do not know it apart from matter—nor, indeed, can we separate matter from it.

> "Nothing in this world is single,
> All things, by a law divine,
> Into one another's being mingle."

And here, we feel the poverty of language. We would not have our thoughts influenced by words, but in the attempt to avoid this we find our expressions too often becoming confused, and the ideas conveyed obscure.

I will illustrate as best I can. When the magnetic steel is brought into the vicinity of the iron particle, the latter responds. Nothing has been added as to its substance, there is nothing but what was there before. The profound mathematician may see, "with intellectual eye," some entangled molecular process, but ordinary men are content with saying, "it is polarized." True, this tells us nothing. Before it was dead, now it quivers with excitement; remove the steel and it dies again, and yet it has parted with nothing of its material substance; the energy is latent, only awaiting the presence of the already excited steel, and to this it will instantly respond. Perhaps diamagnetic action would be a better illustration, as this produces profound and complex changes in *all* matter, which the ordinarily received theories of magnetism cannot explain. A similar property (the illustration is, I grant, a somewhat gross one, but I take it because it is a property of all matter) is what we call 'universal gravitation." We do not understand this, but it is thinkable as a property, even for atoms, and as still a property, though forever concealed, if every other atom but one should be annihihilated. It differs, however, from (polarity, or) life force in this: the energy exhibited depends on the mass, without regard to structure, material, or intervening medium. When that wonderful compound termed protoplasm is formed, the simplest condition we yet know of living matter, not, so far as we can show, by union of its elements in our chemical laboratories, but under the action of a previously existing similar compound, we have what naturalists consider "the basis of life," from which the cell wall is elaborated, and finally, in a continually ascending series, all complex organic structure.

In thus building from the little lump of protoplasm, amorphous, or rather polymorphous, and (as popularly considered) without individuality, all living structure, and admitting the possibility of doing this, we must not forget that the mystery of life is quite as inexplicable in the amoeba as in man, and that evolution does nothing more than "transport the conception of life's origin to an indefinitely distant past." In associating, therefore, with the atom a force, or power of

polarity, if you choose to so consider it, which, when manifested under the proper surroundings, constitutes it no more a *molecular*, but an *organic* unit, we only step on another rung of the ladder, whose foot rests on earth, but whose end is lost in infinity.

But a little while ago I was looking at some minute living diatoms. They were busily moving hither and thither—one of those pretty and interesting sights which so early and strongly arrest the attention of microscopists in the study of the marine and fresh water algae. I was looking at these apparently little less than simple cells, but all alive. A sudden movement of the tube—perhaps by a drowsy nodding of the head and so striking it, for I had been dreaming of that far-off mystery of life, which, the more I pursued it, still entrenched itself deeper and deeper in the secret chambers of atomic particles, continually eluding my grasp—and the consequent sharp click of the object glass against the cover, brought me back to common life. Alas! fragments of those pretty diatoms which but a few moments before, all busy and full of life, had so charmed me, were sweeping madly through the field. No more order, no more beauty—all a hopeless wreck. Where was the life? Where now the power that once controlled this chaos? Everything was there—the wonderful arrangement indeed was disturbed, but all the particles of silex, all the carbon and the nitrogen and the hydrogen were there. Chemically all was the same as before; but the life, where was that? I believed in the conservation of energy, but when, how and where was this life force, if ever, to show itself, again? These are serious questions, and on a grand scale what I have just described for diatoms is going on all around us. We call it death—physical death—and by it, wonderful paradox, we live. The lost polarity of the atom (I use this expression for want of other words) when an organic structure is broken up, returns when again that atom finds itself with the proper surroundings. Its own life energy, if I may so term it, accompanies it in all its rounds; masked or dimly shadowed in crystallic force in the solid rocks of the everlasting hills, anon trembling in the presence of some protoplasmic jelly, and then, an air-born child of life, glowing in the beautiful flowers and graceful verdure of the summer landscape; and finally, in the grand cycle, it becomes a part of man, constituting his very physical strength, his animal life, and in its most harmonious development builds np the matchless form of lovely woman out of clay. Life now appears but the manifestation of individual activities, and growth as a perpetual absorption of nature. Everywhere youth breaks forth in age, the one great terminal mystery of reproduction, rejuvenesence in

some shape, contributing in all its varied forms to progressive development. To use the words of Goethe,

> "All the forms resemble, yet none is the same as another,
> Thus the whole of the throng points at a deep hidden law."

Yes, a law by which the world is renovated and developed; and now we find it is not the germ first, but the organism; and it is the germ elaborated by the organism which is affected by the principle of variation, and the organism by that of natural selection.

And here, in the almost hopeless attempt to define the arrangement of the atoms, and the polarity, or life, in the building of the germ, the microscope fails us—nay, possibly may deceive us. The minute diatom in which I know the germ-producing process is going on, has been called a simple cell, and its colorless and colored fluids have been termed structureless, for we can see no structure there; and yet, what marvelous molecular processes, far beyond the reach of our microscopes, are going on, how infinitely minute the variation, conceivable but not perceivable; no limit to the capability, and therefore, potentially, embracing all possible development.

But marvelous and wonderful as this physical development is, or may be, we must believe that it leads up to something more than the play of atom life. Science may show that atoms live; and if, after all, Mr. Lockyer's idea of possibly but one or two elemental subtances is correct, it may be no very difficult thing to do this; but when one asks, what of man, his powers of speech, of abstract thought, what of his hopes, his aspirations, his fears and his affections? Is this molecular life his final condition? Must I confess that Science gives no answer here? Shall I say that she looks coldly on and sees the material cycle completed, and that man is no more to her than the lichen on the rock—nay, that so far as the life is concerned, that of the lichen is the more wonderful, for by it the solid rocks are disintegrated, and out of their substance a living thing is built; and as the light of a candle, which all along has maintained its form, though particle after particle of carbon and hydrogen have been entering in, and coming out in a new combination, that as the light dies when the wick is charred or the supply fails, so it is with man, and that human organization has no other final cause than the preservation of the individual and the continuation of the species?

Science, dealing only with the world that is, must indeed look upon man as an object of natural history—as a sharer only of animal and vegetable life; and there is, as Gray has said, "a meanness in our ignoring this tie, which, if more realized, would make

us more humane." As we descend in the scale of physical existence, it becomes impossible to define where thought—shall we say reason?—begins; nay, we must admit that the highest state of mere intellectual attainment, a state which is only manifested at the expense of molecular changes, is a legitimate outcome of natural causes, and that the development of mind cannot be separated from its substratum—Nature. If, then, natural philosophy, if all physical science is restricted to objects of sense, and if our experiments can never carry us outside of matter, these are but the steps by which we ascend to the evidence of mind, finding in the very structure and mechanism a sure foundation for what we recognize as truth. Animal instincts, though undignified by the name of reason, most surely guide and lead them even in the remotest outcome to all that is good and useful for them, and this without knowledge or perception on their part; shall we follow with less confidence those intuitions and higher instincts, on which abstract reasoning rests, as less surely conducting us to all that is good and true, thus denying that a uniformity of plan pervades all nature? Shall Science, which has already given us such priceless things, yet in its highest aspect give us no religion, no overruling Providence—practically taking away God and finding nothing else? True, the scientist has often said this is not his mission; but is it so? Does silently and steadily undermining the creeds give to man the power to be great and strong? Is there nothing worth living for but evolution? Must all noble, worthy effort be resolved into differentation, and all tenderness, love and hope considered as but the legitimate outgrowth of the survival of the fittest? "Two things," said Immanuel Kant, "fill me with awe—the starry heavens and the sense of moral responsibility in man;" and the same awe every "scientific investigator" must feel. By the proper study of the things visible, we must pass the limits of physical causation and material action and be constrained to acknowledge a sublime moral cause. In advancing from the region of facts to that of laws, evolution itself may help us, saying, with the Apostle, "Howbeit that was not first which was spiritual, but that which is natural, and afterwards that which is spiritual." In the long ascending series, ever from simpler to more complex, we find the harmony completed in man. As Dryden says:

> "From harmony, from heavenly harmony,
> This universal frame began.
> From harmony to harmony
> Through all the compass of the notes it ran,
> The diapason closing full in man."

And now, in this completed harmony, his whole being trembles in the presence of the Eternal Spirit. He perceives the laws and is ask-

ing for the causes of natural phenomena. His perfected humanity is quivering with the breath of life; and even as the needle, which, before tempering, trembled at the presence of the magnet, only to become quiet when that was withdrawn, now, when tempered, takes to itself the magnetic force, and, "true as steel," in darkest night or wildest storm, proclaims, "this is the way," so has it been with man. Who can tell when and where that tempering was effected, when and where that perfect complex organism was evolved, which not only felt with every other living thing the presence of the spirit, but became its living temple, now no longer body and soul, with the beast, but body, soul and spirit?

At the call of a bell, rung by some unseen force, one listens and hears a well-known voice, faint indeed, and far off—a voice whose very tones, traveling along the electric wire often thrill the heart, as well as address the mind. Man makes the subtile ether, by his words, tremble along the copper molecules. It is no wonder now, only a fact; but what possibilities does it open up to thoughtful minds. Is man's perfected humanity less exquisitely wrought, less capable of responding when its Creator speaks, than the copper wire, the small steel magnet and the iron disc, which some cunning workman has put together? May I go just one step farther? It is perhaps bold, but why should I shrink from saying it, since it is truly experimental reasoning upon a matter of fact, applied to our own existence? If then we believe, aside from scientific proof (and I am sure that the number of those who do not believe is very small), if we believe in a future state of existence, and that "we sow not that body that shall be," but another, which is indeed composed of the poor stuff constituting our animal frames here, if we believe this, then is there not something, even in science, that may help us here? Something which is growing in meaning every day, but whose full interpretation we may never know? What then of that ethereal medium out of which Clerk Maxwell built his cells with their elastic walls, their cavities and inrolling elastic balls, in whose arrangements and motions, though we cannot follow him, he saw, with clear mathematical eye, all the properties of dielectric and electric polarization? What of that "perfect fluid," which is neither carbon nor nitrogen, nor any of the protoplasmic material, wherein Helmholtz and Thompson, with their sharp science eyes see "vortex rings," by whose complicated and ever varied motions they explain the properties of grosser matter? We are told, and we can believe it, that some seventeen million of hydrogen molecules can be contained in a cube whose edge is the hundred thousandth part of an inch—a space barely

discernible with our best microscopes; but the hydrogen molecules are gross, compared with those of the ethereal medium, which penetrate every part of so-called solid matter, creeping in at the interspaces, if you will, of glass and metal, so that we cannot remove them from our so-called perfect vacuums, and must acknowledge even here their presence, in explaining the beautiful experiments of Crookes. What of this "perfect fluid?" Is it an unwarrantable "scientific use of the imagination," to think, for we can think it more easily than of elastic balls, and never ceaseless vortices, that when the particles of carbon, sulphur, hydrogen, and all that we call matter here, drop away in the dissolution of the mortal body, that yet, under the mysterious influence of the spirit, this ethereal matter--for matter we must consider it, although it treats all that we call solid here as so much empty space—that this, retaining a form, becomes the spiritual body, that knows no dissolution? Science tells us almost nothing of the properties of this matter, we only know its effects; but, as matter, why should it not constitute, in the final evolution, so much the more important part of man, as in itself it is the most important matter of the universe, reaching out to all worlds? And now, death becomes but the struggle of the impatient spirit "to free itself from the circle of individual activity," and find a closer union with the Father.

Such, gentlemen, have been the thoughts that came in quiet hours, when the world was asleep, and I was trying to study the phenomena of life in the minute organisms which require the highest and best powers of our microscopes. I have neither the time nor the ability to discuss them as I would. I pass them over to you for thought and study. Unreflective minds may, as Lewes says, deem such thoughts and studies trivial occupations for serious men. And they may indeed be pursued "in a trivial spirit, uninspired by a loftier aim, but under their lowest aspect they have still the unalienable value attendant upon all truth; and, under their highest aspect, they teach us something of a noble wisdom which profoundly affects the practical affairs of life, by affecting the temper and direction of our thoughts." The illustrious father of British astronomy, Boyle, when ridiculed for watching the colors of the soap-bubble, says, in a letter to Newton, alluding to this so-called childish occupation, "other persons that come after me will think their time as little misspent in these studies as those did who have gone before me. The works of the Eternal Providence, I hope, will be a little better understood through your labours and mine than they were formerly. Think me not proud for this expression; I look on pride as the worst of sins, humility as the greatest virtue." Nothing can be unworthy of being investigated by

man, which was thought worthy of being made by God. Finally, I venture to hope that the subjects presented have not been uninteresting, for I can attribute your kind attention to no grace of diction, eloquence of speech, or thought on my part.

> "All nature widens upward. Evermore
> The simpler essence lower lies;
> More complex is more perfect, owning more
> Discourse, more widely wise."
>
> —*Tennyson's Palace of Art.*